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ABSTRACT

This unit of instruction deals with the study of X-ray and Gamma Ray Radiographic Testing and infra-red thermal testing of specimens without destruction. Theory and principles are covered in detail. Many known samples are used as standards and considerable laboratory and field use of this equipment is involved. Motion picture films and color slides are listed to be used with the lesson. Goals, specific block objectives, and a bibliography are listed in the booklet. A posttest sample, with answers, is included. (EB)

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AUTHORIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

DADE COUNTY PUBLIC SCHOOLS

Course Outline
AVIATION QUALITY CONTROL - ADVANCED - 9227
(Radiographic and Thermal Testing)
Department 48 - Quin 9227.02

DIVISION OF INSTRUCTION•1973

SE 017 057

ED 093609

DADE COUNTY PUBLIC SCHOOLS
1450 NORTHEAST SECOND AVENUE
MIAMI, FLORIDA 33132

Course Outline

AVIATION QUALITY CONTROL - ADVANCED - 9227
(Radiographic and Thermal Testing)

Department 48 - Quin 9227.02

county office of
VOCATIONAL AND ADULT EDUCATION

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Dr. E. L. Whigham, Superintendent of Schools
Dade County Public Schools
Miami, Florida 33132

December, 1972

Published by the School Board of Dade County

Course Description

9227	48	9227.02	Radiographic and Thermal Testing
State Category Number	County Dept. Number	County Course Number	Course Title

This course consists of X-ray and Gamma Ray Radiographic Testing and infra-red thermal testing of specimens without destruction of the specimen, or what is called Nondestructive Testing (NDT). Theory and principles are covered in detail. Many known samples are used as standards and considerable laboratory and field use of this equipment is conducted.

Clock hours: 135

PREFACE

The following quinmester course outline will serve as a guide for the high school or adult trainee in testing, inspecting and checking parts and materials to insure the quality and reliability of the finished product.

This outline consists of eight blocks of work or 135 hours of instruction which are subdivided into several units each. These blocks will involve the techniques of X-ray and gamma ray, radiographic testing and infra-red thermal testing of specimens. These inspection methods of parts and specimens are known as nondestructive testing or NDT.

Adequate laboratory time and actual experience on aircraft and other equipment will be provided to develop skills in the student.

The student is expected to be proficient in, not just familiar with, the nature and the application of these techniques.

The student will work with and receive substantial drill in the actual equipment used in the NDT field.

Motion picture films and color slides will be used to bring into the classroom the application of these techniques.

Study periods, group discussions, and extensive use of textbooks and training manual will be used. These are listed along with references and periodicals in the Bibliography.

This outline was developed through the cooperative efforts of the instructional and supervisory personnel, the Quinmester Advisory Committee, and the Vocational Teacher Education Service, and has been approved by the Dade County Vocational Curriculum Committee.

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with Suggested Hourly Breakdown

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How Gamma Rays are Produced	1
Producing the Radiograph Image	1

II. EQUIPMENT USED IN RADIOGRAPHY (15 hours)

The X-ray Tubehead	1
Basic High Voltage Circuit	2
Control Panels	2
Darkroom Equipment	2
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III. TECHNIQUES OF MAKING THE RADIOGRAPH (35 hours)

Specimen and Film Relationship	2
Focal Film Distance	3
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Using Exposure Charts and Slide Rules	3
Technique of Double Film Exposure	3
Darkroom Techniques	3
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Effects of X-rays on Human Tissues	4
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Principles of Operation of Infrared Thermal Testing Instruments 5

VI. TECHNIQUES IN OPERATING AND SERVICING EQUIPMENT USED IN THERMAL TESTING (20 hours)
Cooling Detector to Cryogenic Temperatures 5
Capacity of Tester 5
Operation of Controls 5
Interpretation of Readout 6
Care and Servicing Equipment 6

VII. ADVANTAGES AND LIMITATIONS OF INFRARED THERMAL TESTING (10 hours)
Portability of the "Temp Test" Machine . . 6
Metallic and Non-Metallic Specimens . . . 6

VIII. SAFETY AND WORK PRECAUTIONS IN INFRARED THERMAL TESTING (5 hours)
Safe Methods of Handling and Storage of Liquid Nitrogen 6
Heat Lamps as a Source of Burns 6

IX. QUINMESTER POST TEST

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GOALS

The aviation quality control student must be able to:

1. Develop skills in the use of nondestructive testing equipment.

2. Develop the attitudes of patience and persistence to gain maximum accuracy.

3. Develop the habits of cleanliness of person and work area.

4. Be aware of the responsibility involved in his chosen work.

5. Maintain the standards required for the field.

6. Control quality of the finished product.

SPECIFIC BLOCK OBJECTIVES

BLOCK I - HOW X-RAYS ARE PRODUCED

The student must be able to:

1. Identify and name at least 5 parts of the X-ray tube.
2. Explain, by diagramming, what is the effective focal spot.
3. Explain, in writing, in not less than 25 words, how X-rays are produced.
4. Name at least four sources of gamma rays.
5. Explain, with the use of a drawing or photograph, how an isotope camera works.
6. Explain, in writing, the terms <u>X-ray quality</u> and <u>X-ray quantity</u>.

BLOCK II - EQUIPMENT USED IN RADIOGRAPHY

The student must be able to:

1. Physically check out the cooling circuit of a 160 KV unit.
2. Explain, by diagramming, three X-ray beam configurations.
3. Perform a complete "warm up" of a 160KV portable unit after the unit has not been used for 30 days.
4. Make up at least two preliminary exposure charts from X-rays of step wedges.

BLOCK III - TECHNIQUES OF MAKING THE RADIOGRAPH

The student must be able to:

1. Make four exposures of step wedges at different KV settings on one sheet of 14 x 17 inch film.
2. Make a radiograph of at least four small specimens making the exposure from students prepared exposure chart.
3. Calculate at least four exposure samples using the slide rule exposure calculator.
4. Develop at least six full size sheets of exposed X-ray film by hand.

5. Name three faults found in the exposed X-ray films and discuss these faults.
6. Name three faults found in the exposed X-ray film from processing and explain these faults.
7. Analyze at least six radiographs using viewer and specimen.

BLOCK IV - SAFETY AND WORK PRECAUTIONS IN RADIOGRAPHY

The student must be able to:

1. Name and define three measurement terms used in X-ray safety.
2. Explain the banking concept and work out a maximum permissible dose for a hypothetical X-ray technician.
3. During an actual X-ray exposure, define and mark off an unrestricted area using a survey meter.
4. Calculate, using the inverse square law, an unrestricted area for a given exposure.

BLOCK V - THERMAL TESTING

The student must be able to:

1. Explain the infrared spectrum and infrared energy.
2. Trace heat flow through at least two specimens.
3. Explain, using a block diagram or flow chart, what takes place in the "temp test" machine.

BLOCK VI - TECHNIQUES IN OPERATING AND SERVICING EQUIPMENT USED IN THERMAL TESTING

The student must be able to:

1. Prepare the "temp test" machine for operation.
2. Fill out a work sheet showing control settings and results of test.
3. Run complete tests on at least three specimens with known defects.
4. Fill out inspection reports on above tests.
5. Interpret recorder readouts on the above tests by comparing with specimen.
6. Show his ability to care for equipment by cleaning optical parts and replacing a paper roll in facsimile recorder.

BLOCK VII - ADVANTAGES AND LIMITATIONS OF INFRARED THERMAL TESTING

The student must be able to:

1. Run a successful test on at least one non-metallic specimen.
2. Locate, by test, water contamination in a honeycomb structure.

BLOCK VIII - SAFETY AND WORK PRECAUTIONS IN INFRARED THERMAL TESTING

The student must be able to:

1. Demonstrate his ability to handle liquid nitrogen properly.
2. Show sufficient knowledge of electric circuitry to avoid shocks and burns.

BLOCK IX - QUINMESTER POST TEST

The student must be able to:

1. Satisfactorily complete the quinmester post test.

Course Outline

AVIATION QUALITY CONTROL - ADVANCED - 9227
(Radiographic and Thermal Testing)

Department 48 - Outline 9227.02

I. PRINCIPLES AND THEORY OF RADIOGRAPHY

A. How X-rays Are Produced
   1. The X-ray tube
      a. The envelope
      b. The cathode and anode in the X-ray tube
      c. The filament and focusing cup
      d. The window and its location
      e. The effective focal spot
   2. The electron source in the X-ray tube
   3. The electron target

B. How Gamma Rays Are Produced
   1. Natural sources of gamma rays
   2. Artificial sources of gamma rays for radiography
      a. Cobalt - 60
      b. Iridium - 192
      c. Thullium - 170
      d. Cesium - 137
   3. Radioisotope half life as a measure of intensity
   4. Isotope cameras and their function

C. Producing the Radiograph Image
   1. Analogy to photography
   2. Image sharpness
   3. Image distortion
   4. X-ray wave length
   5. X-ray quality
   6. X-ray quantity
   7. Hard and soft X-rays
   8. Scatter or secondary radiation

II. EQUIPMENT USED IN RADIOGRAPHY

A. The X-ray Tubehead
   1. Gaseous electrical insulation for X-ray tube

II. EQUIPMENT USED IN RADIOGRAPHY (Contd.)

2. Liquid cooling circuits for tubehead
3. X-ray beam configurations
   a. Hemispherical beam
   b. Annular beam
   c. Lateral beam

B. Basic High Voltage Circuit
1. Transformer types
2. Inverter systems
3. Generator circuits

C. Control Panels
1. Kilovolt (KV) meter and control
2. High, low KV switch
3. Indicator and warning lights
4. Milliampere (MA) meter and control
5. Timers
6. Circuit protective devices

D. Darkroom Equipment
1. Developing and fixing tanks
2. Rinse water
3. Safe light, types and filters
4. Timers for development control
5. Thermometers used for temperature control
6. Automatic equipment its size and cost

E. Films Used in Radiography
1. Films classified as to four types
2. Film contrast
3. Film grain
4. Relative film speeds
5. Film characteristic curves
6. Film sensitivity
7. Film resolution
8. Film latitude
9. Film density charts
10. Film cassettes and ready pack

III. TECHNIQUES OF MAKING THE RADIOGRAPH

A. Specimen and Film Relationship

III. TECHNIQUES OF MAKING THE RADIOGRAPH (Contd.)

B. Focal Film Distance (FFD)
   1. Effect on exposure of film to specimen distance
   2. The inverse square law and its effect on exposure
   3. Effect on sharpness and distortion

C. Accessory Equipment
   1. Diaphragms, collimators and cones for radiation control.
   2. Filters for radiation control
   3. Screens for intensification
   4. Masking and blocking to reduce secondary radiation
   5. Penetrameters for determining sensitivity
   6. Step wedges for density control
   7. Positioning devices
   8. Identification markers

D. Using Exposure Charts and Slide Rules
   1. How to make an exposure chart
   2. Computing exposure from an exposure chart
   3. Computing exposure from an X-ray exposure slide rule
   4. Selecting the proper kilovoltage (KV)

E. Technique of Double Film Exposure
   1. Purpose of double film exposure
   2. Selection of films to use

F. Darkroom Techniques Manual
   1. Developing the X-ray film
      a. Time and temperature to control development
      b. Visual inspection
      c. Agitating during development
   2. Rinsing the film
   3. Fixing the film
   4. Washing the film
   5. Drying the film

G. Automatic Processing
   1. Temperature control for proper density
   2. Mixing the chemicals
   3. Techniques in starting and shuting down the processor
   4. Care of the processor

III. TECHNIQUES OF MAKING THE RADIOGRAPH (Contd.)

H. Faults Found in Exposed X-ray Films
   1. Unsharpness
   2. Too high contrast
   3. Improper density
   4. The cause of fogging
   5. Artifacts found on film from darkroom handling

I. Interpretation of the Radiograph Image
   1. Types of viewers
   2. Use of magnifiers with the viewers
   3. Checking density against prepared density strips
   4. Checking sensitivity by observing the penetrameter
   5. Orientation of the specimen to the radiograph

J. Advantages and Limitations of X-ray Testing
   1. Depth limits of subsurface discontinuities
   2. Crack visibility in relation to the X-ray beam
   3. Permanent record always available
   4. Personal safety as a limiting factor
   5. Portability of equipment

IV. SAFETY AND WORK PRECAUTIONS IN RADIOGRAPHY

A. Effects of X-rays on Human Tissue

B. Terms Used in the Measurement of X-rays
   1. Roentgen (r)
   2. Roentgen equivalent man (REM)
   3. Radiation absorbed dose (RAD)

C. Maximum Permissible Dose
   1. The banking concept
   2. Allowable working time
   3. Working distance
   4. Radiation levels in unrestricted areas
   5. Exposure to minors
   6. Personal monitoring
   7. Shielding

IV. SAFETY AND WORK PRECAUTIONS IN RADIOGRAPHY (Contd.)

D. Safety Equipment
   1. Signs, lights, and signals
   2. Radiation survey equipment
      a. Dosimeters
      b. Film badges
      c. Gieger counters

V. THERMAL TESTING

A. Theory of Infrared Energy
   1. The infrared spectrum
   2. Heat flow in materials
   3. Infrared sensors
      a. Thermal detectors
      b. Photo detectors
   4. Optics used in thermal testing
   5. Resultant signal processing
   6. Optical scanning techniques

B. Principles of Operation of Infrared Thermal Testing Instruments

VI. TECHNIQUES IN OPERATING AND SERVICING EQUIPMENT USED IN THERMAL TESTING

A. Cooling Detector to Cryogenic Temperatures
   1. Location of photo-voltaic detector and dewar
   2. Handling of liquid nitrogen

B. Capacity of Tester
   1. Size of specimen tester will handle
   2. Heat source area
   3. Scan width of "temp test" machine

C. Operation of Controls
   1. Sensitivity meter and control
   2. Heat source lamps
   3. Scan speed rheostat
   4. Carriage speed rheostat
   5. Mode selection switch
   6. Signal levels for recorder

VI. TECHNIQUES IN OPERATING AND SERVICING EQUIPMENT USED IN THERMAL TESTING (Contd.)

D. Interpretation of Readout

E. Care and Servicing Equipment
   1. Removing moisture from liquid nitrogen dewar
   2. Cleaning optical parts of tester
   3. Servicing facsimile recorder
      a. Replacing paper roles in recorder
      b. Cleaning recorder and helix strip
      c. Replacing worn loop electrode
      d. Replacing worn helix strip

VII. ADVANTAGES AND LIMITATIONS OF INFRARED THERMAL TESTING

A. Portability of the "temp test" machine

B. Metallic and Non-metallic Specimens
   1. Honeycomb structures and laminates
      a. Unbonds between skin and core
      b. Voids
   2. Airfoil Sections
      a. Corrosion under skin and in joints
      b. Water contamination in honeycomb core
      c. Unbonds between skin sections

VIII. SAFETY AND WORK PRECAUTIONS IN INFRARED THERMAL TESTING

A. Safe Methods of Handling and Storage of Liquid Nitrogen

B. Heat Lamps as a Source of Burns

IX. QUINMESTER POST TEST

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1. Nondestructive Testing, Radiographic Testing, Classroom Training Handbook. San Diego, California: General Dynamics Convair Division, 1967. Pp. 144.

Supplementary References:

2. Berger, Harold. Nondestructive Testing. Oak Ridge, Tennessee: USAEC Division of Technical Information Extension, 1967. Pp. 38.

3. Extension Course Institute, Testing, 53250-03-0965. Chanute Air Force Base, Illinois USA. Pp. 80.

4. McMaster, Robert. Nondestructive Testing Handbook, Two Volumes. New York: Ronald Press Company, 1963. Pp. 54 and 42.

5. Nondestructive Testing Methods. Technical Manual T.O. 33B-1-1. U.S. Government Printing Office, 1967. Pp. 320.

Periodicals:

6. Material Evaluation. Chicago: American Society for Nondestructive Testing. Monthly.

Films:

1. Quality Assistance. 16mm. 19 min. Color. Sound. Aviation School.

A P P E N D I X

Quinmester Post Test Sample

QUINMESTER POST TEST
(Radiographic and Thermal Testing)

Name_____ Date_____ Score_____

Multiple Choice Test Items

Each question below is followed by four possible answers, select the best answer and mark your answer sheet accordingly.

1. An excellent radiograph is obtained under given conditions of exposure with the film located at a distance of 36 inches from the target of the X-ray tube. If the film is now placed only 18 inches from the target, and all exposure conditions except time are held constant, the new exposure time will be
   a. unchanged
   b. longer by approximately 80 per cent
   c. shorter by approximately 55 per cent
   d. only about 25 per cent as long as the original exposure time

2. An excellent radiograph is obtained under given exposure conditions with a tube current of five milliamperes and an exposure time of twelve minutes. If other conditions are not changed, what exposure time would be required if the X-ray tube current could be raised to ten milliamperes?
   a. 24 minutes
   b. 12 minutes
   c. 6 minutes
   d. 3 minutes

3. In film radiography, penetrameters are usually placed
   a. between the intensifying screen and the film
   b. on the source side of the test object
   c. on the film side of the test object
   d. between the operator and the radiation source

4. Lead is frequently employed in shielding against radiation from X-ray and gamma ray sources because of its
   a. extremely low cost
   b. high absorption for a given thickness and weight
   c. ability to emit electrons when irradiated
   d. ability to diffract alpha particles

5. The penetrating ability of an X-ray beam is governed by
   a. kilovoltage or wave length
   b. time
   c. milliamperage
   d. source-to-film distance

6. Cobalt 60 used in nondestructive testing emit
   a. alpha particles
   b. neutrons
   c. gamma rays
   d. X-rays

7. Three liquids which are essential to process and exposed film properly are
   a. stop bath, acetic acid, and water
   b. developer, stop bath, and H_2O_2.
   c. developer, fixer, and water.
   d. acetic acid, fixer, and stop bath

8. The time required for one half of the atoms in a particular sample of radioactive material to disintegrate is called
   a. the inverse square law
   b. a curie
   c. a half life
   d. the exposure time

9. The ability to detect a small discontinuity or flaw is called
   a. radiographic contrast
   b. radiographic sensitivity
   c. radiographic density
   d. radiographic resolution

10. Movement, geometry, and screen contact are three factors that affect radiographic
   a. contrast
   b. unsharpness
   c. reticulation
   d. density

11. Upon completing an X-ray exposure and turning the equipment off
   a. personnel should wait for a few minutes before entering the exposure area
   b. personnel should wear a lead-lined apron before entering the exposure area

c. personnel may enter the exposure area without fear of radiation exposure
d. personnel should take a reading with a geiger counter before entering the exposure area

12. The most widely used unit of measurement for measuring the rate at which the output of a gamma ray source decreases is the
a. curie
b. roentgen
c. half life
d. MEV

13. Small amount of exposure to X-rays or gamma rays
a. will have cumulative effect which must be considered when monitoring for maximum permissible dose
b. will be beneficial since they build up an immunity to radiation poisoning
c. will have no effect on human beings
d. will have only a short-term effect on human tissues

14. A dose of _____ would be dangerous, if not fatal, if applied to the entire body in a short period of time.
a. 1.5 to 15 r
b. 25 to 70 r
c. 200 to 800 r
d. all of the above doses would most likely be fatal

15. When radiographing a part which contains a large crack, the crack will appear on the screen as a
a. dark, intermittent or continuous line
b. light irregular line
c. either a dark or light line
d. fogged area on radiograph

16. X-ray tube current is controlled by
a. the current passing through the filament
b. the distance from the cathode to the anode
c. the type of material used in the target
d. the voltage and waveform applied to the X-ray tube

17. The voltage and waveform applied to the X-ray tube by a high voltage transformer determines the
    a. quantity of radiation
    b. duration of exposure
    c. quality of radiation
    d. X-ray beam divergence

18. As the kilovoltage applied to the X-ray tube is raised
    a. X-rays of longer wavelength and more penetrating power are produced
    b. X-rays of shorter wavelength and more penetrating power are produced
    c. X-rays of shorter wavelength and less penetrating power are produced
    d. X-rays of longer wavelength and less penetrating power are produced

19. In order to increase the intensity of X-radiation
    a. the tube current should be increased
    b. the tube current should be decreased
    c. the test specimen should be moved further from the film
    d. a lower kilovoltage should be applied to the tube

20. A general rule often employed for determining the kilovoltage to be used when X-raying a part is
    a. the kilovoltage should be as high as other factors will permit
    b. the kilovoltage should be as low as other factors will permit
    c. the kilovoltage is always a fixed value and cannot be changed
    d. the kilovoltage is not an important variable and can be changed over a wide range without affecting the radiograph

21. Materials which are exposed to gamma radiation or to X-rays below a few million volts
    a. should not be handled for at least 3 minutes after exposure has ceased
    b. should be stored in a lead-lined room
    c. will not be dangerous to handle after exposure to radiation has ceased
    d. should be monitored by means of a geiger counter

22. Excessive exposure of film to light prior to development of the film will most likely result in
    a. a foggy film
    b. poor definition
    c. streaks
    d. yellow stain

23. If an exposure time of 60 seconds was necessary using a 4-foot source-to-film distance for a particular exposure, what time would be necessary if a 2-foot source-to-film distance is used and all other variables remain the same?
    a. 120 seconds
    b. 30 seconds
    c. 15 seconds
    d. 240 seconds

24. The duration of an exposure is usually controlled by
    a. controlling the milliamperage
    b. a timer
    c. controlling the source-to-film distance
    d. a choke coil in the filament transformer

25. Kilovoltage, exposure time, and source-film distance are three of the most important X-ray exposure factors that can be controlled. A fourth such exposure factor is
    a. focal spot size
    b. temperature
    c. filament-to-focal spot distance
    d. milliamperage

26. When the minute silver grains on which the X-ray film image is formed group together in relatively large masses, they produce a visual impression called
    a. air bells
    b. graininess
    c. reticulation
    d. frilling

27. For best results when manually processing film, solutions should be maintained within a temperature range of
    a. 60°F and 75°F
    b. 65°C and 75°C
    c. 75°F and 85°F
    d. 75°C and 85°C

28. The small area in the X-ray tube from which the radiation emanates is called the
    a. diaphragm
    b. focal spot
    c. focusing cup
    d. cathode

29. The most common material used to provide protection against X-rays is
    a. high density brick
    b. an alloy of 70% steel and 30% copper
    c. tungsten
    d. lead

30. A photographic record produced by the passage of X- or gamma rays through a specimen onto a film is called a
    a. fluoroscopic image
    b. radiograph
    c. isotopic reproduction
    d. none of the above

31. The "temp test" facsimile recorder readout provides a
    a. 2 to 1 C scan presentation
    b. 1 to 1 B scan presentation
    c. 2 to 1 A scan presentation
    d. 1 to 1 C scan presentation

32. Scanning in the "temp test" machine is done
    a. mechanically
    b. by physical means
    c. by optical means
    d. by neither of the above

33. What item listed below could not be successfully tested by the "temp test" machine?
    a. Crack in a forging
    b. Large inclusion in a casting
    c. Corrosion
    d. Lack of bond in honeycomb structure

34. The "temp test" machine measures heat flow in a specimen. Is this statement correct?
    a. Yes
    b. No

35. A typical scan speed for the "temp test" machine would be

a. 2 ft. per second
b. 1 inch per second
c. 2 inches per second
d. 1 ft. per second

ANSWER KEY TO QUINMESTER POST TEST
(Radiographic and Thermal Testing)

1.	d	13.	a	25.	d
2.	c	14.	c	26.	b
3.	b	15.	a	27.	a
4.	b	16.	a	28.	b
5.	a	17.	c	29.	d
6.	c	18.	b	30.	b
7.	c	19.	a	31.	d
8.	c	20.	b	32.	c
9.	b	21.	c	33.	a
10.	b	22.	a	34.	a
11.	c	23.	c	35.	b
12.	c	24.	b		